Fringe Projector Study of the Brighter-Fatter Effect

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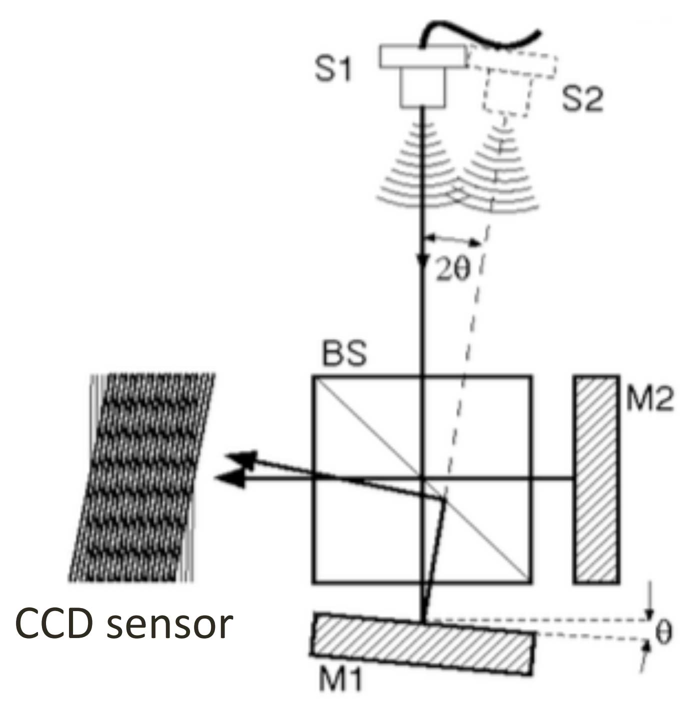
Method of Study

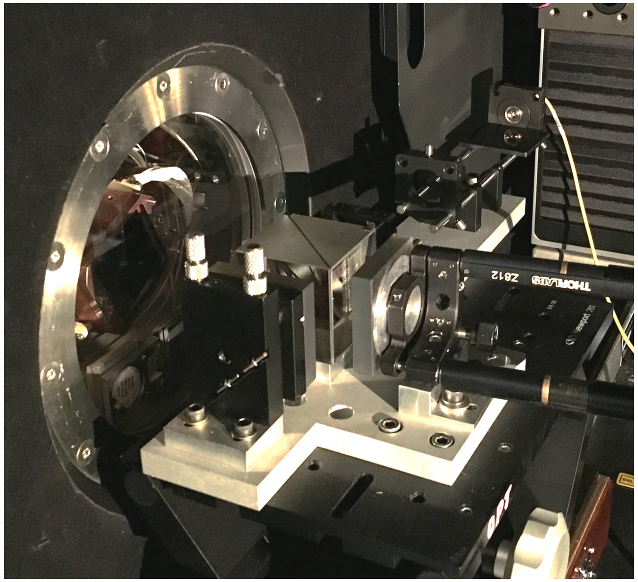
- The study of the Brighter-Fatter Effect is a study of how the PSF changes with intensity
- Observing the PSF at high and low intensities within one exposure could allow for studying the Brighter-Fatter Effect
- A Michelson Interferometer can be used to create a fringe pattern projected onto a CCD
- If the peaks and troughs of the fringes vary significantly enough they will have different shapes due to the Brighter-Fatter Effect

Michelson Interferometer

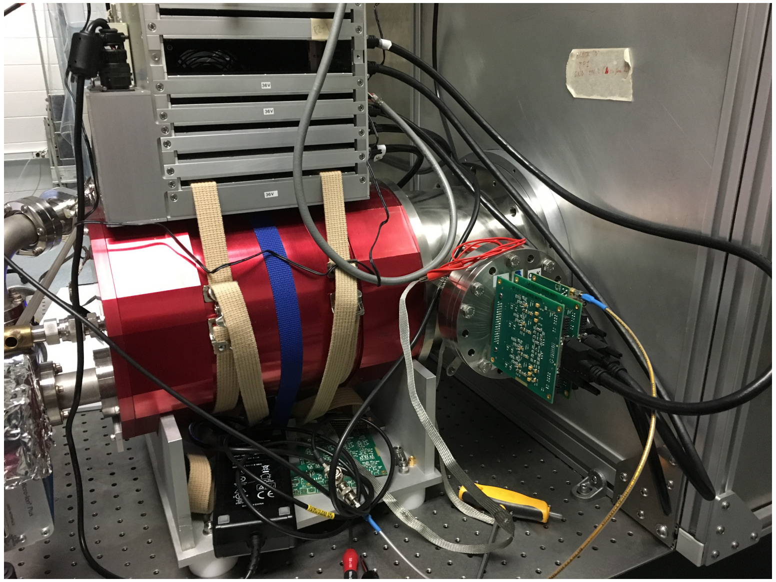
- A 532 nm laser is aimed at a beam splitter with two adjacent mirrors
- By adjusting the angles at which the two mirrors sit the beams create patterns of constructive and destructive interference
- This is a very reliable way for creating light fringes with a sinusoidal shape



Lab Setup



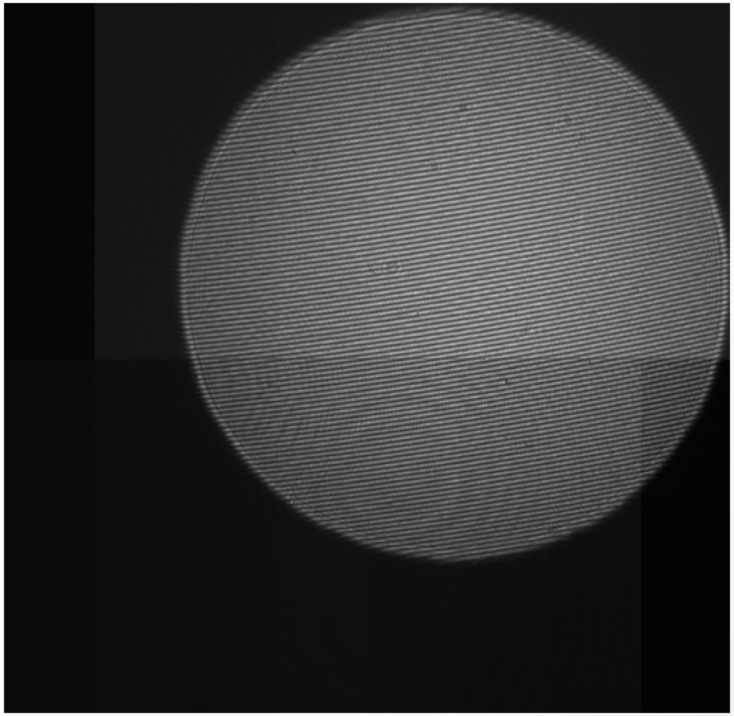
Michelson Interferometer
inside of a dark box



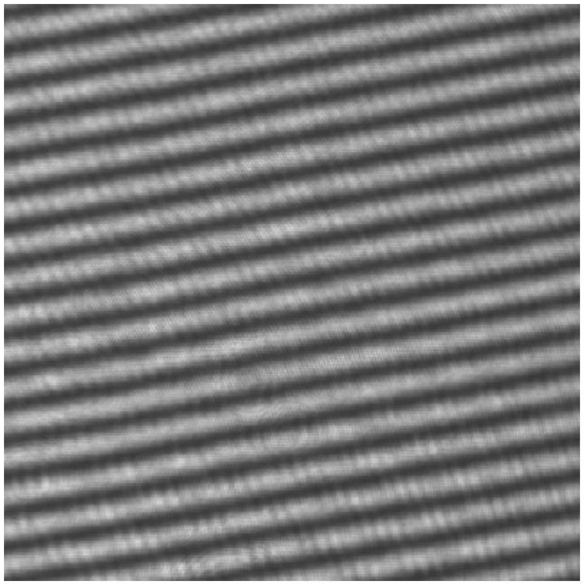
Dewar containing CCD,
cooled to -100° C

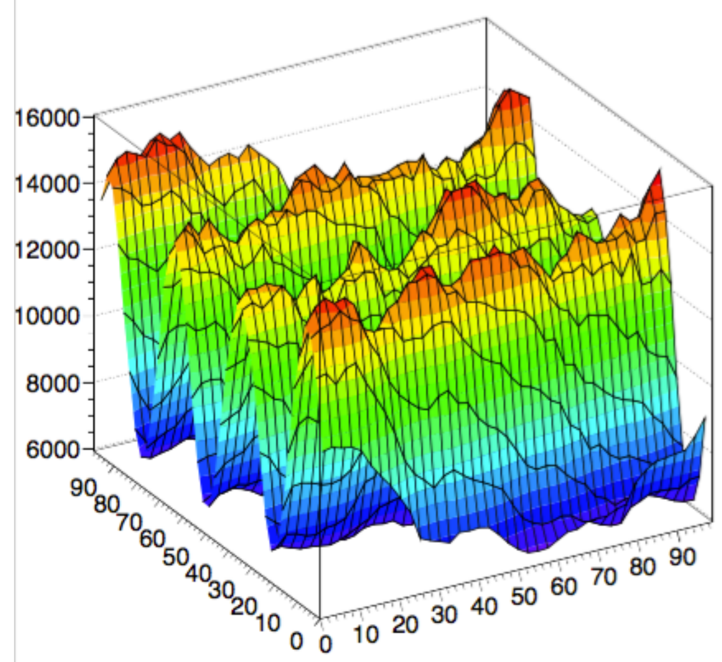
Datasets

- The setup and initial data was taken by Alex Karlis and Peter Takacs last summer (his talk is on SAWG meeting page from August 13th 2015)
- The lab setup has been revived with the help of Ivan Kotov and new data has been taken with an improved contrast between the peaks and troughs of the fringes
- By turning the laser off during readout the smearing has been significantly reduced
- 3 datasets at 2 different spatial frequencies were taken last week
- A fully assembled image is shown to the right



Data and Analysis



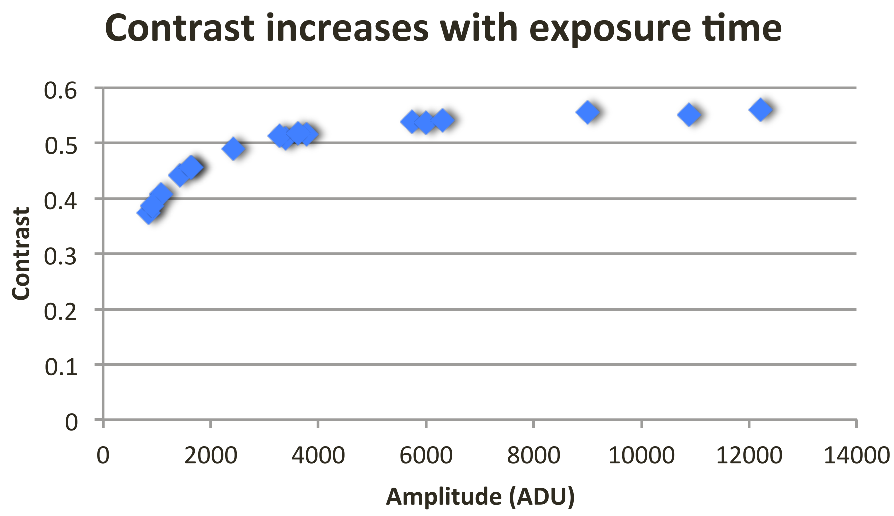


- Only a few oscillations are needed to fit the data so only a small portion of the image is needed at a time
- The fringes fits files can be fit with an altered sine wave to measure the distortion from the peak to the trough
- The amplitude does modulate slightly, but I hope to correct for this in the future

Contrast

- Have a larger contrast means the differences between the peaks and troughs due to the BF effect are more noticeable
- The calculation for contrast was as follows:

$$contrast = \frac{max - min}{max + min}$$

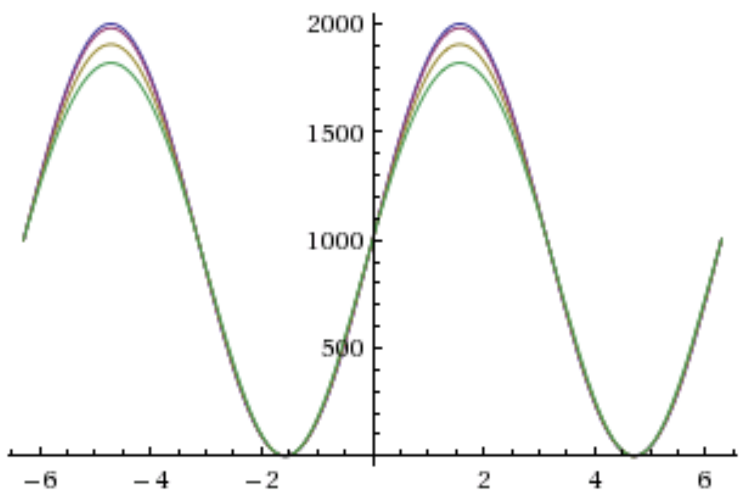


“Ad hoc function” Fit

- For a rough estimation of the effect an approximation of a distorted fit can be made

$$f(x) = k + m_x x + m_y y + Ae^{\lambda(1+\sin(kx'+\phi))}\sin(kx'+\phi)$$

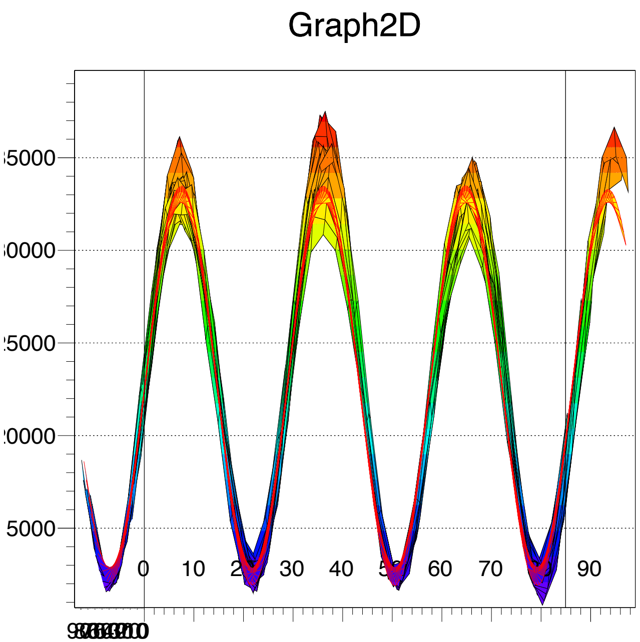
$$x' = x\sin\theta - y\cos\theta$$

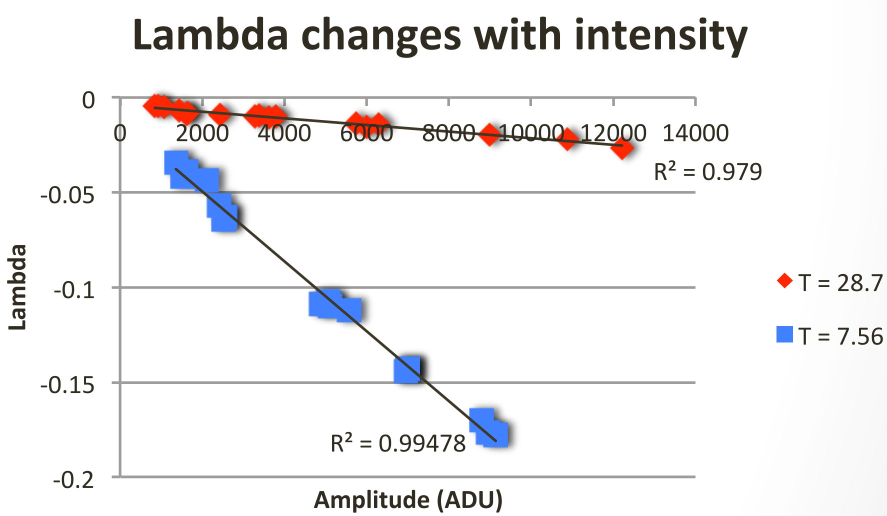


This shows values of lambda equal to 0, -0.01, -0.05, and -0.1

"Ad hoc function" Fit

- The crests change differently compared to the troughs
- The parameterization for the BF effect fits the data taken very well and shows an increase in the lambda value with increased exposure time





1D Model of the BF Effect

- The fringe pattern from a Michelson interferometer should follow the fit from the following integral

$$\rho(x') = \int_{-\infty}^{\infty} A\sin(kx)\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(x-x')^2}{2\sigma^2}}\,dx$$

- To allow for this fit to change for the effect the PSF (σ) must depend on flux (represented as f)

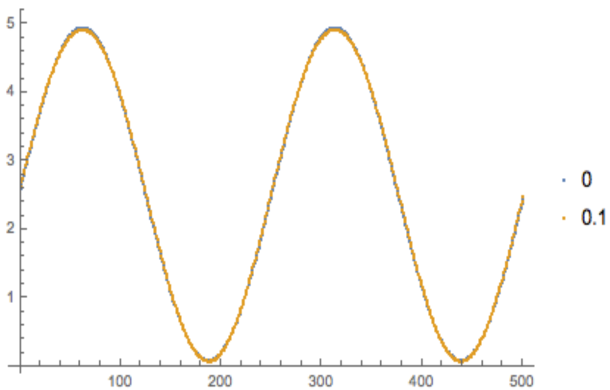
$$\sigma = \sigma_o(1+\delta f)$$

- This integral is best solved through numerical integration

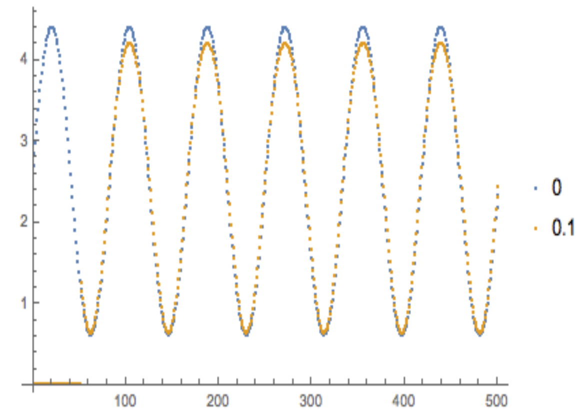
1D model examples

- Solving the integration allows for certain variables to be investigated, revealing a dependency on the period of oscillation

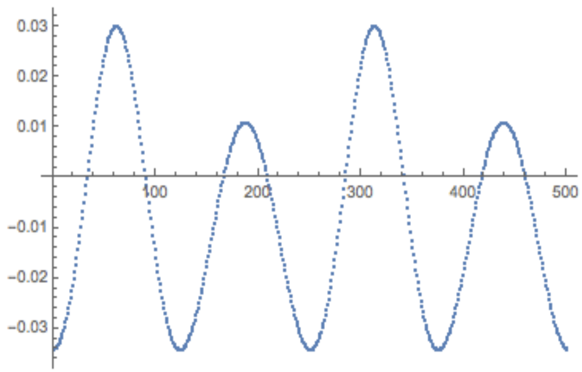
T=28 pixels

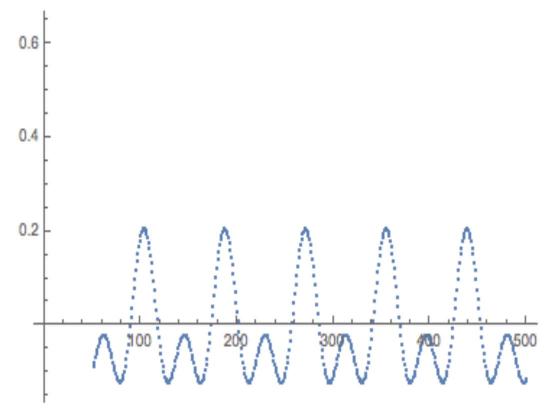


T=8 pixels



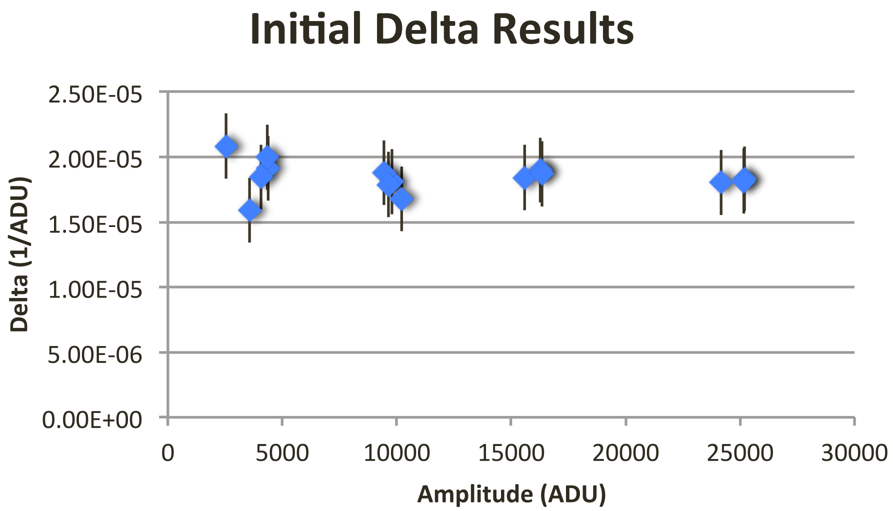
Difference





Continuing work

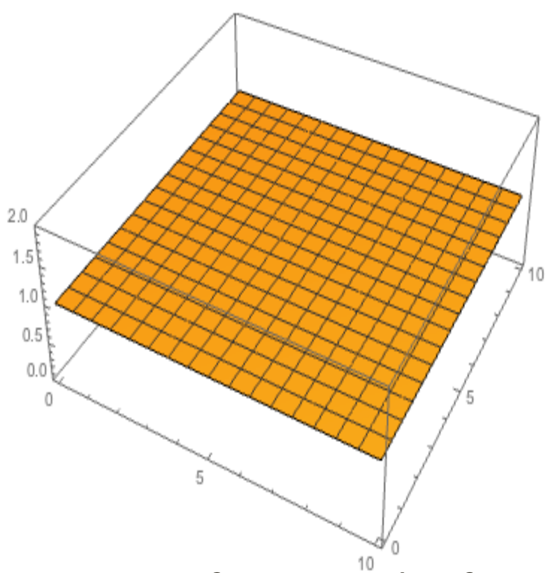
- Currently the numerical integration fit does not converge properly with the data, but does show a reasonably constant delta



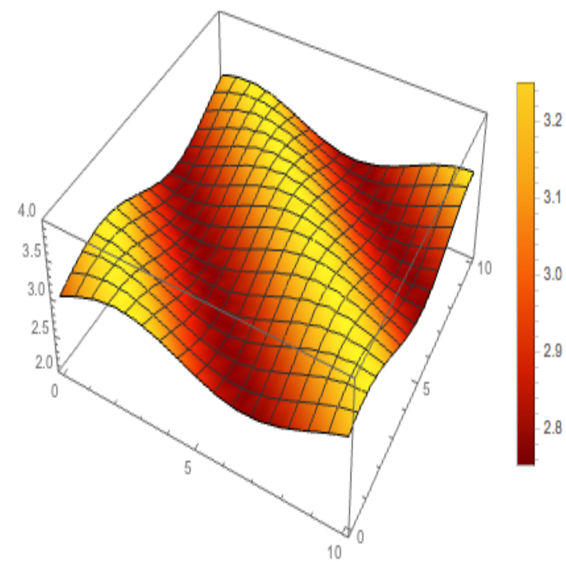
- Once it does converge with the data the delta can be measured at various points to calculate an average, this will give the slope of the PSF with respect to flux

Ratio between fits

- Another analysis to study the BF effect would be to take the ratio between different files to observe non-uniformities
- The ratios between two files at the same intensity should be uniform and very close to 1, while ratios between two files at different intensities will vary due to the BF effect



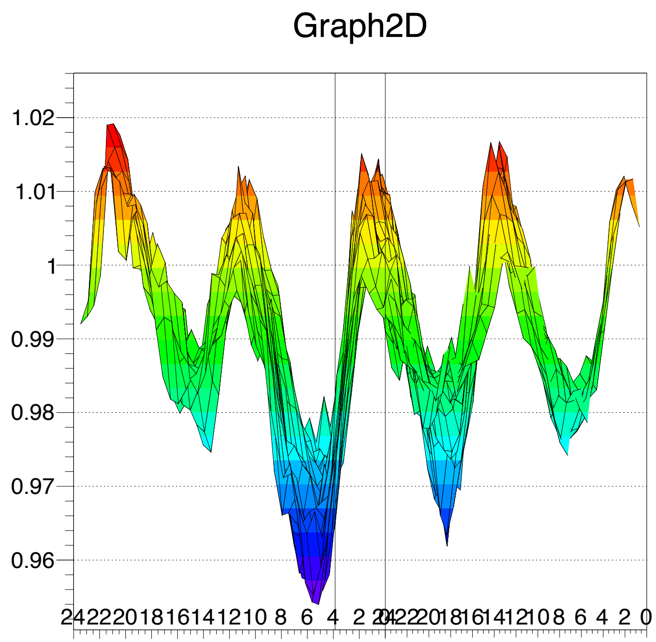
Ratio of two similar fits



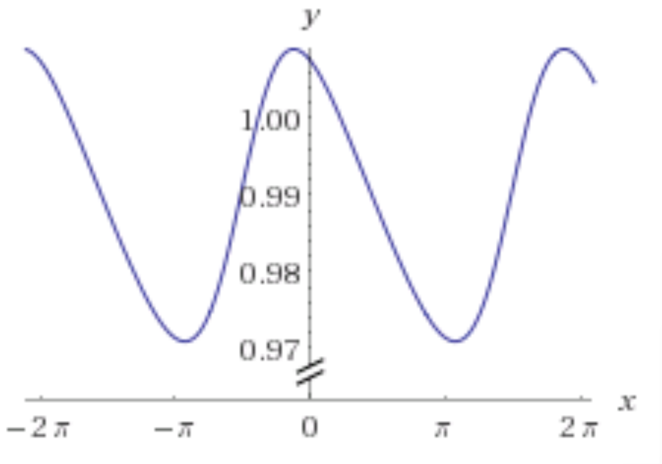
Ratio of two different fits

Ratio between fits

- Unfortunately it appears that there is a phase shift problem between fits files



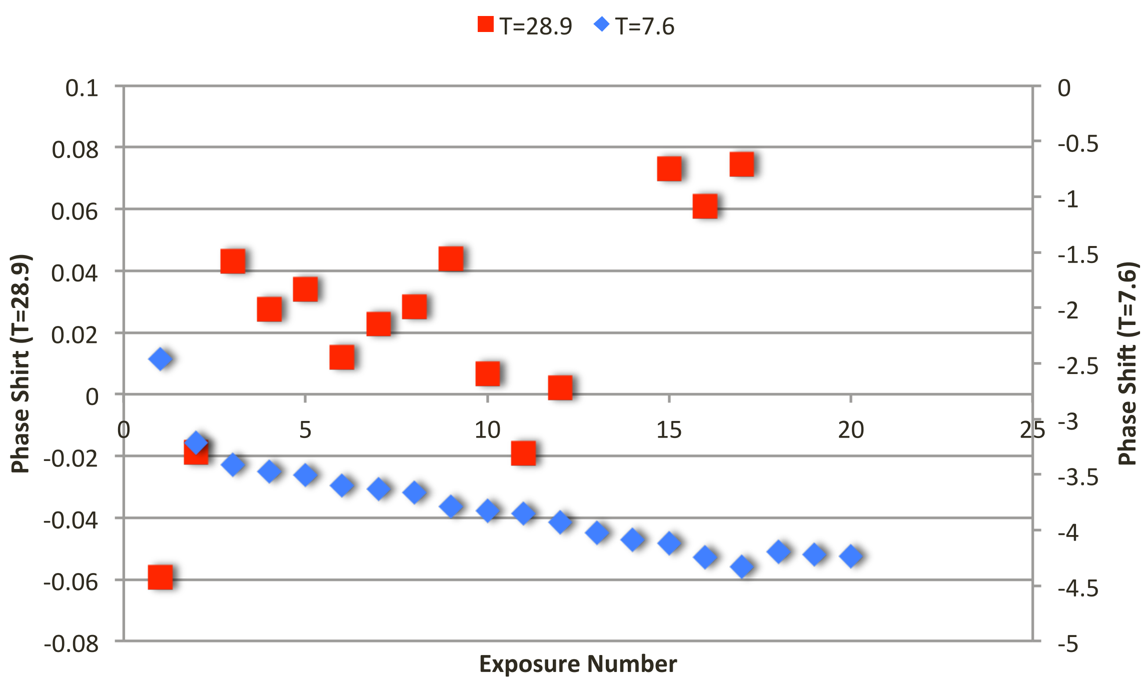
Ratio of real data



Ratio of two sine waves with a phase shift introduced

Phase shift inconsistencies

- There seems to be a systematic error in the phase shift from exposure to exposure



Improvements to be made

- I plan on adding a mask and a dark tube to the lab setup to increase the contrast
- The phase shift problem needs to be looked into, could have multiple sources
- The numerical integration fit needs to converge as well